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Development of Bait for the Management of Coffee Bean Weevil, *Araecerus fasciculatus* in Stored Cocoa

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Authors' contributions

This work was carried out in collaboration between all authors. Author AE designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors BKM and PDK managed the analyses of the study. Author PKT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted at the Laboratory of the Horticulture Department of Kwame Nkrumah University of Science and Technology between January and March, 2012 within temperature and humidity ranges of 18–32°C and 63–85%, respectively. The purpose of the investigation was to develop an effective insecticidal cassava bait to control insect pests of cocoa in storage using *Araecerus fasciculatus* (De Geer) as model species. A completely randomized design was used for the study. It was conducted in a five-roomed glass cage of 60 cm x 60 cm x 200 cm with the backside made of a net to improve aeration in the cage. It was observed that *A. fasciculatus* preferred sun-dried chips to fresh chips, fermented dough, flour and cocoa beans and that soaking of sun-dried chips in brown sugar solution of 500 g per litre of water further enhanced the preference. Deltamost emerged superior to Fastrack and Confidor insecticides by registering 4–6 minutes of lethal time, 21–30 days persistence and attract-and-kill potential of 76.7 – 86.7% of infested bagged cocoa beans. However, cassava bait at 25% of Deltamost insecticide was at equal strength ($p < 0.05$) with the 50 and 75% of the label dosage and should be the obvious choice for the insecticidal cassava bait preparation.

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1. INTRODUCTION

Cocoa (*Theobroma cacao* L.) is a cash crop of huge economic significance in the world and the key raw material for chocolate manufacturing [1, 2]. It forms the major agricultural export commodity for several producing countries in West and Central Africa, such as Cote d'Ivoire, Ghana, Nigeria and Cameroon [3]. Côte d'Ivoire, Ghana and Indonesia are the leading producers of cocoa in the world in terms of land area under production and production volumes. Ghana plays a major role as the second largest cocoa producing country with production suddenly rising to about 540 000 metric tonnes during the 2003/2004 crop year and reaching 720, 000 metric tonnes which constituted 20.7% of world production as at the end of 2009. Its production was reported to have reached 1.0 million metric tonnes by end of 2011 according to Ghana Cocoa Board [4]. In Ghana, cocoa has been labelled 'the golden pod' owing to the pivotal role it plays in the nation's economy. It is cultivated on about 1.5 million hectares of land by some 800,000 families in six out of the ten regions. It is cultivated almost exclusively by small-holder farmers with average farm sizes of about 4.0 ha and mean production yield of 246.4 kg/ha [5,6]. Ghana's cocoa sector employs millions of people both formally and informally because it is the predominant farming activity. The cocoa sector alone contributed up to 22.4 percent of the total foreign exchange earnings of Ghana during the 2002 season. According to Dwinger (2010), cocoa contributed nine (9) percent of Ghana's gross domestic product (GDP) in 2008 [7].This contributed sixty-three (63) percent of the entire foreign export earnings accrued from the agricultural sector. According to Osei (2007), a good quality cocoa is one devoid of insect infestation and high levels of chemical residues in the produce [8]. The sale of cocoa that has any of these attributes may suffer outright rejection by the buyer or may be subjected to high arbitration cost to the country. Bateman (2010) reported that insect infestation and chemical residues in cocoa beans are major challenges confronting the cocoa industry in Ghana [9] and according to Jonfia-Essien et al. [10], fumigating cocoa beans with methyl bromide and phosphine is the current method of controlling insect pests of stored cocoa. The use of methyl bromide however, was banned in developed countries in 2005 and it was to take effect in developing countries in 2015 because of its depleting effect on the ozone layer [11]. On the other hand, the EPA proposed a ban or restrictive use of phosphine because it is highly toxic and insects rapidly build resistance to it [12]. Environmental concerns, chemical residues, insect resistance and worker safety issues have increased interest in alternative, safer, selective and ecologically acceptable toxophores and novel methods of application including the use of insecticidal baits [13]. Though dry cassava chips have been found to be preferred by a primary pest of stored cocoa, *Araecerus fasciculatus* De Geer Boateng and Chijindu, 2008, much work has not been done in the use of baits to control insect pests of cocoa beans as well as using cassava as an attractant in insecticidal bait formulation [14]. The purpose of this investigation, therefore, was to develop an effective insecticidal cassava bait to control insect pests of cocoa in storage using *A. fasciculatus* as model species with the following specific objectives: 1. determine the cassava preparation that is most preferred by *A. fasciculatus*; 2. determine the effect of brown sugar on the preference of *Araecerus* to cassava; 3. identify the most effective chemical for the cassava bait preparation and 4.determine the efficacy of insecticidal cassava bait in controlling *Araecerus* infestation of bagged cocoa beans under cage.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at the laboratory of the Horticulture Department of the Kwame Nkrumah University of Science and Technology between January and March, 2012. The experiment was performed within temperature and humidity ranges of 18-32°C and 63-85% respectively.

2.2 Experimental Cage and Study Design

A transparent glass cage of 60 cm x 60 cm x 200 cm was constructed with the backside of the cage made of a net to improve aeration. The top had four breaks at 40 cm interval where partition glasses inserted created five equal cabins. Each cabin had a sliding door on the front side and the base was made of a transparent glass. The various set up were laid out using a completely randomized design.

2.3 Culturing of Experimental Insects

Culture of *Araecerus fasciculatus* (De Geer) was raised from a field strain of parent stock obtained from Ashanti Bekwai. An insect haven was created in a garden behind the Quality Control (COCOBOD) office by drying cassava chips on a raised platform and any *A. fasciculatus* that was attracted was captured with a pooter. The culture was prepared using ten Kilner jars with dry cassava chips sterilized in an oven at a temperature of 60°C for 24 hours. The moisture content of the sterilized chips was reduced to 9 %, measured using an Aqua Boy. The jars were filled with the sterilized cassava chips to three-quarters full before introducing the insect. The insects were secured in the jars with meshed covers to provide adequate aeration in the bottles. The jars were then placed on plastic trays containing industrial oil to prevent contamination of the culture by other insects. The insects were sieved off 12 days after introduction and the contents kept for fresh insect immergence.

2.4 Data Collected

The following data were collected during the study;

2.4.1 Evaluation of the preference of *A. fasciculatus* for four cassava preparations

The four partitions of the cage were removed and 300 g each of four cassava preparations (fresh chips, sun-dried chips, fermented dough and flour) from the Yebesi local variety and cocoa beans as the control were simultaneously placed on the floor of the cage. Twenty five day-old insects were introduced and the cage closed. The four partitions were inserted after 24 hours and insects present on each cassava preparation and the cocoa used were counted. This was repeated three times by randomizing the arrangement of the treatments in the cage and the number of *A. fasciculatus* attracted to each treatment 24 hours after introduction into the cage was recorded.

2.4.2 Experiment to determine the preference of *A. fasciculatus* to dry cassava chips and chips immersed in brown sugar solution

A solution was prepared using 500 g of brown sugar and one litre of water. One kilogram of dry chips was soaked in the solution and the mixture was transferred into a black polyethylene bag and kept for 12 hours. A comparison was made by placing 300 g each of dry cassava chips, soaked chips and cocoa as the control in the cage and twenty day-old *A. fasciculatus* were introduced. The experiment was repeated three times by randomizing the arrangement of the treatments in the cage. The number of *A. fasciculatus* attracted to dry cassava chips, chips immersed in brown sugar solution and cocoa beans 24 hours after introduction into the cage were recorded.

2.4.3 Preparation of insecticidal cassava bait

The cassava bait was prepared using 500 g of brown sugar dissolved in one litre of water [15] and varied concentrations (25%, 50% and 75% of manufacturer's application rate) of the three chemicals [13] each added separately and mixed thoroughly. One kilogram of dry cassava chips of sweet tasting variety (Yebesi) was soaked in each of the prepared solution and kept in black polyethylene bags for 12 hours. The chips were then picked out of the solution, air-dried for 30 minutes, and used as bait. The various concentrations of chemicals used in preparation of the bait are shown in Table 1.

Table 1. Application rates of pesticides used for the preparation of cassava bait

Pesticide	Manufacturer's application rate/L (water)	25% application rate/L (water	50% of application rate/L (water)	75% of application rate/L (water
Confiodor 20 SC/ml	2.5	0.63	1.25	1.88
Deltamost/ml	111	27.75	55.5	83.25
Fastrack 10SC/ml	15	3.75	7.5	11.25

Note: Deltamost contains 2.5 % deltamethrine, 0.3 % bioallethrine and 11% piperonyl butoxide while Confidor contains 20 % Immidachloprid and Fastrack, 10 % Alpha-cypermethrine

2.4.4 No-choice test to determine the efficacy of the cassava insecticidal bait

Thirty grams each of the cassava baits prepared with three different concentrations of the three insecticides were placed in transparent plastic jars with meshed lids and day-old *A. fasciculatus* was introduced. The time of insect coming into contact with the bait and the time it dropped dead (lethal time) were taken and the experiment repeated three times for each bait. On the other hand, 30 g of each of the cassava bait with cassava chips soaked in only brown sugar solution as the control were also put into separate transparent plastic jars, three of day-old insects were introduced to each treatment at 24 hourly intervals and insect mortalities were recorded. This was repeated until further introduction of day-old insects did not result in any mortality and the number of days was recorded. The experiment was repeated three times for each treatment.

2.4.5 Experiment to evaluate insecticidal cassava bait for efficacy *against A. fasciculatus* on infested bagged cocoa beans under cage

Cassava baits at three different concentrations of each of the three pesticides (Fastrack 10 SC, Confidor 20 SC and Deltamost) were prepared using sun-dried cassava chips. The baits weighing 100 g each were introduced into each partition of the cage containing a stack of five bags of cocoa beans in miniature jute sacks. The jute sacks with dimensions of 7 cm wide and 16 cm deep were filled with 1.5 kg each of cocoa. Both the bait and the cocoa were placed in the cage and twenty day-old A. *araecerus* were introduced. The number of *A. araecerus* attracted and killed by the bait after 12, 24, 48 and 72 hours were counted. A partition containing cocoa with dry cassava chips immersed in brown sugar solution was used as the control since there was no standard bait to compare with and the experiment was repeated three times.

2.5 Statistical Analysis

Data collected were subjected to Analysis of Variance using Statistix Software version 9.0. Differences between treatment means were compared using the least significant differences at 1% probability level.

3. RESULTS

3.1 Evaluation of the Preference of *A. fasciculatus* among Four Cassava Preparations

There were significant differences ($p < 0.05$) between the preferences for cassava preparations by *A. fasciculatus*. Dry cassava chips were most preferred by *A. fasciculatus*, which was significantly different, attracting 14 of the insects representing 57.2% (Fig. 1). This was followed by fermented dough, which scored an average preference of 21.3%. There were however no significant differences ($p > 0.05$) between the cassava dough and the fresh cassava chips in terms of their preference by the insect. The least preferred cassava preparation was the flour, which scored an average preference of 2.8%. However, it was not statistically different from that of cocoa beans (1.2%), which served as the control.

3.2 Comparison of the Preference of *A. fasciculatus* between Dry Cassava Chips and Chips Immersed in Brown Sugar Solution

There were significant differences ($P < 0.05$) in the attraction of day-old *A. araecerus* to dry cassava chips and that of chips immersed in brown sugar solution (Table 2). Chips immersed in brown sugar solution attracted 81.2% of the insects as compared with 16% for the dry cassava chips, which was also significantly different from those attracted to cocoa (2.8%), which was used as the control for the experiment.

3.3 Determination of the Lethal Mean Time for on Insecticidal Cassava Bait at Varied Concentration of Three Insecticides

From Table 3 there was varied efficacy among the insecticide-prepared baits towards *A. fasciculatus*. Most of the baits killed *A. araecerus* between 4 and 30.3 minutes after it had fed on it, but baits prepared with 25 and 50% Confidor and 25 % Fastrack of the recommended application rates took two to three days to cause mortality and were, therefore, dropped in subsequent investigations.

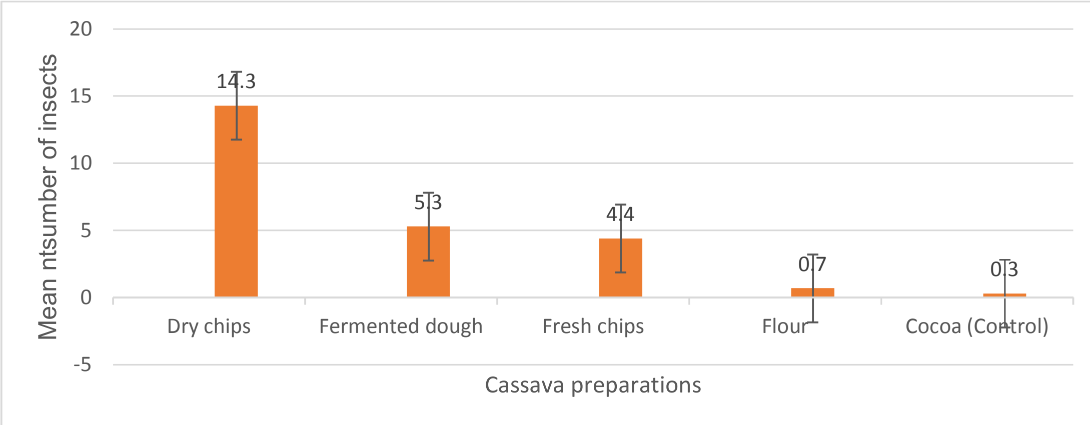

Fig. 1. Mean preference of *A. fasciculatus* to cassava preparations

However, six treatments in addition to the control were used in subsequent experiments.

Table 2. Mean preference of *Araecerus* to dry cassava chips and chips in brown sugar solution

Product	Mean number of insects
Chips in brown sugar solution	20.30a (81.20%)
Dry chips	3.70b (16%)
Cocoa (control)	0.30c (2.8%)
CV	15.92

Notes: Percentage of insects attracted in parenthesis. Means followed by same letter does not differ significantly at p < 0.05

From Table 3, there were significant differences (p < 0.05) in the lethal time for the various insecticidal bait preparations. Deltamost at 75 % recorded the shortest lethal time of 4 minutes which was significantly different from those of Confidor at 75%, and Fastrack at 50 and 75%, but not insignificantly different (p > 0.05) when compared with Deltamost at 25 and 50% of the recommended concentrations. Fastrack at 50% of the recommended application rate recorded the longest lethal time of 30.33 minutes which was significantly longer than all the other bait preparations. There were no significant differences (p > 0.05) between the confidor at 75% and fastrack at 75% with both recording 14.33 and 10.67 minutes, respectively. The differences between deltamost at 50% and 25% and fastrack 75% were also statistically insignificant.

Table 3. Mean lethal time taken to record insect mortality

Pesticide concentration	Mean lethal time/minutes
Fastrack 50%	30.33a
Confidor 75%	14.33b
Fastrack 75%	10.67bc
Deltamost 25%	6.33cd
Deltamost 50%	6.00cd
Deltamost 75%	4.00d
CV	23.27

Means followed by same letter does not differ significantly at p < 0.05

3.4 Comparism of Persistence of Insectides at Varied Concentration in Cassava Bait

The persistence of the various levels of the insecticide on the baits varied significantly at p < 0.05 (Fig. 2). Generally, Deltamost recorded longer number of days (above 20 days) for all the three levels with Deltamost at 75% of the recommended level having the longest persistency of 29.67 days which was significantly longer than the other pesticide concentrations. Deltamost at 25 and 50% followed respectively with 21.00 and 25.33 days of persistence, which were individually significantly different from each other. The two levels of Confidor recorded the least number of days for persistency with 50% concentration recording the shortest persistency of 2.67 days whilst 75% followed with 5.33 days. They were however not statistically different at P > 0.05 from each other. On the other hand, Fastrack 50 and 75% recorded 9.33 and 13 days of persistence respectively which were different from each other.

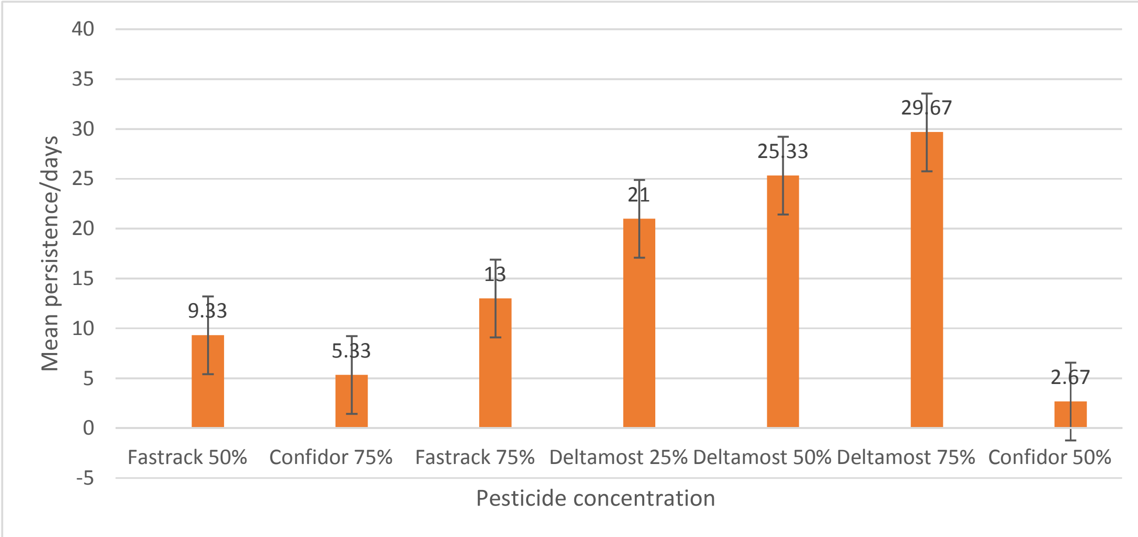

Fig. 2. Persistence of pesticides in baits

The control (dry chips immersed in brown sugar solution) did not register any mortality during the test period and was, therefore, excluded in the statistical analysis.

3.5 Evaluation of Insecticidal Cassava bait for Efficacy against *Araecerus*-infested Bagged Cocoa Beans under Cage

At 12 hours of introducing insects to treatment, Deltamost treated baits performed significantly better ($p < 0.05$) than the other pesticides. From Table 4, Deltamost at 75% killed the highest number (40 %) of insects introduced and it was however not significantly different ($p > 0.05$) from Deltamost at 50% and Deltamost at 25% which recorded 36.7% and 35.0% insect mortality, respectively. Fastrack at 75% and Confidor at 75 % recorded 11.7% and 5.0% mortality rates respectively which were not significantly different from each other, though they were different from the three levels of Deltamost baits. Fastrack at 50% also recorded 5.0% mortality rating. The control (dry chips soaked in brown sugar solution) recorded 0.0% mortality rate but was not different from Deltamost at 50% and Confidor at 75%.

At 24 hours after treatment, Deltamost generally continued to perform significantly better ($p < 0.05$) than the two other chemicals, but in this case, Deltamost at 50% recorded 60% insect mortality, which was not different statistically ($p > 0.05$) from Deltamost at 75% (58.3% mortality) and Deltamost at 25% (51.7% mortality) the recommended rates. These were followed by Dastrack at 75% the recommended dosage, which recorded an average insect mortality of 33.3%, but was not significantly different from Confidor at 75% the recommended rate (28.3% mortality). Confidor at 75% was also not different statistically ($p > 0.05$) from Fastrack at 50% the recommended rate, which recorded insect mortality of 15%. However, the performance of Fastrack at 50% the recommended dosage was not different from the control, which recorded 1.7% mortality of Araecerus introduced into the cage.

There was a general increase in the mortality with increasing time. At 48 hours after introduction of the insects, Deltamost continued to perform significantly better ($p < 0.05$) than the other pesticides. Deltamost at 25% the recommended rate recorded the highest mortality of 83.3%, but that was not significantly different ($p > 0.05$) from Deltamost at 75% and 50%, which recorded 81.7 and 73.3% mortalities respectively. On the other hand, Fastrack at 75% of the recommended rate was not statistically different ($p > 0.05$) from Confidor at 75% the recommended dosage. However, it performed significantly better than Fastrack at 50%, which in turn was not different from Confidor at 50%. The control was the least performer with 1.7% mortality.

Table 4. Evaluation of cassava bait for efficacy against *A. fasciculatus* on infested bagged cocoa beans under cage

Treatment	Conc. of bait (%)	Time (hours)			
		12	24	48	72
Deltamost	75	40.00a	58.35a	81.65a	86.65a
	50	35.00a	60.00a	73.35a	76.65ab
	25	36.65a	51.65a	83.35a	85.00a
Fastrack 10SC	75	11.65b	33.35b	53.35b	63.35bc
	50	5.00bc	15.00cd	36.65c	55.00c
Confidor 20 SC	75	5.00bc	28.35bc	45.00bc	48.35c
CV		33.89	21.75	14.54	14.43

After 72 hours of exposure, Deltamost at 75 % of the recommended dosage emerged the best (86.7% mortality), but that performance was not significantly different ($p > 0.05$) from Deltamost at 25% and 50% which recorded mortality rates of 85 and 76.7% respectively (Table 4). However, Deltamost at 50% did not show significant differences from Fastrack at 75% of the recommended dosage with 63.3% insect mortality. On the other hand, there were no significant differences between Fastrack at 75%, Fastrack at 50% and Confidor at 75% of the recommended dosages. Only 1.7% mortality was recorded in the control, which was the least mortality recorded.

4. DISCUSSION

4.1 Evaluation of the Preference of *A. fasciculatus* to Four Cassava Preparations

The four preparations were from the same source of cassava (Yebesi local variety) however, their attractiveness to the insect varied significantly, making sun-dried chips the obvious choice.

According to Metcalf (1992), the development and processing of plants and plant parts produce chemical compounds, which generate olfactory or gustatory stimuli that convey specific behavioral messages to specific species involved in ecological interrelations of the food web [16]. In his assertion, insects have sensory receptors, which are used to perceive semiochemicals in the form of volatiles from food. It could, however, be inferred that the sun-dried cassava chips emitted compounds that attracted *A. fasciculatus* more than the other cassava preparations. Chijindu and Boateng (2008) reported *that A. fasciculatus* preferred fermented and sundried chips probably because of their lower densities, which make it easier to penetrate as well as olfactory cue emitted [14]. The difference between the attractiveness of dry cassava chips and the flour is striking and needs to be explained. Producing flour from the same chips and for the chips to be more attractive implies that breaking the cassava into powder might have reduced the critical signals that stimulate behavioral patterns leading to preferred oviposition sites, satisfactory food supplies and aggregation with receptive mates or shelter [16]. Furthermore, Viswanadham et al. [17] found rice bran more preferred by *Spodoptera litura* (Fabricius) than rice fine husk, jowar flour, and ragi flour. Adu-Mensah et al. [18] also reported the suitability and preference of sun-dried cassava chips by *A. fasciculatus*, which supports the result obtained from this study. According to Wakefield [19], food baits contain complex mixture of volatile, only some of which will be detected by the insect to elicit a behavioral response. No work has been done on food bait comparisons involving cocoa beans and cassava chips. However, it could be inferred that the dry cassava chips produced volatiles that attracted *A. fasciculatus* more than the cocoa beans. This could be likened to a food bait experiment by Foster et al. [20] who compared wheat bran, apple pumice and food waste using rangeland grasshopper species and found apple pumice and food waste superior.

4.2 Effect of Brown Sugar on the Preference of *A. fasciculatus* to Dry Cassava Chip

In comparing the preferences of *Araecerus* to cassava and chips immersed in brown sugar solution, dry cassava chips immersed in brown sugar solution was preferred to dry cassava chips. Generally, several researchers have reported that sugars are good insect attractant. Tublad (1947) reported that sugar added to wheat bran, creolite and water could achieve over 90% attract-and kill of the larvae of *Agrotis segetum* (Schiff) [21]. Devaiah [22] added jaggery to wheat bran to make effective bait against *Spodoptera littoralis* (Boisduval). Twenty per cent molasses was added to wheat flour to attract the fourth instar larvae of *S. litura* [23]. Hiremath et al. [14] standardized bait preparation by the addition of jaggery to water and rice bran. Müller et al. [24] formulated attractive toxic sugar bait, which caused a decline of 90% in mosquitoes in the Bandiagara district of Mali. Barry and Polavarapu (2004) observed that higher concentrations (8, 16 and 32%) of sucrose in baits elicited greater feeding responses in blueberry maggot (*Rhagolettis mendax* Curan) than lower concentrations (4%) and no sugar and concluded that alternative baits should contain at least 8% sucrose, as a significant feeding stimulant and some amount of ammonium acetate as an attractant [25]. In the preparation of attractive toxic sugar bait for the control of *Phlebotomus papatasi* (Scopoli), Muller and Schlein [26] prepared baits with 10% brown sugar, which made effective sprays on barrier fences. These results confirm the attractiveness of the dry chips immersed in brown sugar solution to *A. fasciculatus* than dry cassava chips and cocoa beans.

The chips immersed in the brown sugar solution were so attractive that most of the insects were attracted to it thereby making the dry chips unattractive and as such making it have the same effect as the control (cocoa beans).

4.3 Comparison of the mean Lethal Time for Araecerus on Insecticidal Cassava Bait at Varied Concentrations of Three Pesticides

In this study, Deltamost (deltamethrin synergist with bioallethrin and piperonyl butoxide) in cassava bait was superior at the three levels to both confidor (imidacloprid) and fastrack (alphacypermethrin). Obeng- Ofori (2008a) reported of the potency of deltamethrin in the control of stored product beetles where organophosphates are ineffective [27]. However, deltamost at 75% the recommended dosage had a mean lethal time of 4.0 minutes, which was not matched by any of the treatments. Rint (1989) impregnated sacks with deltamethrin at 75% dosage and recorded 100% mortality of *A. fasciculatus* while cypermethrin at 75% dosage was ineffective [28]. Generally, higher concentrations of the pesticides used in this experiment had shorter knockdown time compared with those of lower concentrations. This could be compared with a laboratory trial conducted by Barry and Polavarapu (2004) in which fly survivorship on six insecticides (acetamiprid, clothianidin, deltamethrin, fipronil, imidacloprid and spinosad) incorporated at 4, 40 and 400 parts per million in protein baits had higher concentrations of insecticides resulting in increased fly mortality [26]. Similarly, Renju (2007) in the evaluation of new insecticides in baits found higher dosages more potent than lower dosages [13]. All the dosages at 75% strength were more toxic which supports observations made by Viswanadham et al. [17] who tested different levels of chlorpyriphos (0.5, 1.0, 1.5 and 2.0%) in bait formulation and recorded higher insect mortalities with higher than lower concentrations. These results might explain why lower concentrations of Confidor at 25 and 50% and Fastrack at 25% the recommended dosages were not potent enough to cause insect mortality within a comparable time The control (dry chips soaked in sugar solution only) did not record any insect mortality which suggests that the mortalities recorded in the treatments with insecticides in the cassava bait were due to the insecticide in the cassava. Rint (1989) recorded 100% survival rate of *A. Araecerus* in the control of the experiment to impregnate sacks with pesticides where there was no pesticide in those bags used as the control of the experiment [28].

4.4 Evaluation of the Persistence of the Pesticides in the Cassava Bait

Deltamost was more persistent than Confidor and Fastrack in the cassava bait against *A. Araecerus* with the 25% of the approved dosage of Deltamost being capable of causing mortality of *A.* A*raecerus* within 24 hours for 21 days in a no-choice experiment while the 75% of the approved dosage recorded the highest with 29.7 days. There is no similar finding in literature to support this finding. However, according to Mangan et al. [29], spinosad bait at different concentrations maintained toxicity against the tropical fruit fly for at least three weeks, which could be compared with the persistence of Deltamost cassava bait against Araecerus. Dilution of the insecticides affected the potency of the bait with time and the higher the concentration of the insecticide in the bait, the more it lasted against *A. fasciculatus.* With respect to each pesticide, 75% strength lasted longer in toxicity than the 50% and that was more potent than the 25% the recommended dosages. Similarly, Revis et al. (2004) assessed the effects of concentration and ageing on the attractiveness and toxicity of GF-120 fruit fly bait to melon flies, *Bactrocera cucurbitae* (Coquillett) [30]. They tested dilutions of 20, 40, and 80 parts per million of active ingredient (spinosad) against water controls and found baits containing higher concentrations more persistent than those containing lower concentrations of spinosad. The control (dry chips immersed in brown sugar solution only) did not register any mortality during the test period. This meant that the pesticides were potent enough to cause mortality of *A. fasciculatus* in the specified periods.

4.5 Evaluation of Insecticidal Cassava Bait for Efficacy against Araecerus-infested Bagged Cocoa Beans under Cage

In this study, insect mortalities caused by the addition of the pesticides to the cassava bait were significantly higher than the control (dry chips soaked in brown sugar without pesticide). The high insect mortalities recorded could be attributed to the use of the pesticides in the bait because no mortalities were recorded in the control experiment. Deltamost was the fastest and most potent attract-and-kill cassava bait, in that at 12 hours after the treatment, more than 35% of the insects introduced had been killed by the bait while the highest performance for both Fastrack and Confidor cassava baits was 12.7%. According to de Groot (2004), Deltamethrin (an active ingredient of Deltamost) is very effective against grain weevils and could be the reason why Deltamost proved much more potent even at lower concentrations and within short exposure time periods [31]. Cassava bait prepared with Deltamost at 25% the recommended dosage was the most effective in attracting and killing *Araecerus* in bagged cocoa beans since at that low rate, the performance was not different from the 75% the recommended dosage within the period of the experimentation. Preparing the cassava bait with Deltamost at 25% the recommended dosage meant reducing cost and load of the chemical in the working environment. Apart from Deltamost pesticide which did not differ among the different concentrations used in the experiment, both Fastrack and Confidor had lower concentrations causing lower mortalities for short periods, but eventually the lower concentrations ended up causing comparable mortalities with higher concentrations. Though both pesticides have not been applied in a similar work before, this observation could be compared with the findings of Bong et al. [32]. In evaluating the effectiveness of imidacloprid (Confidor) against strains of the house fly, *Musca domestica* (Linnaeus), they reported that mortalities due to scatter and paint-on applications increased with increased time of exposure. The study revealed that between the 50 and 75% the recommended dosages of fastrack, 75% the recommended dosage was superior at attracting and killing the insect at 12 hours after treatment than the 50%, but at 72 hours after treatment, however, their ability to cause mortality were not different. This finding could be compared with the test of persistence and effects of dilution of hydrolyzed-protein-edible-insecticide bait conducted by Mangan et al. [29] for the control of tropical fruit flies. They reported that lower concentrations of spinosad (80 ppm) killed fewer flies when measured over short periods than higher concentrations (200 ppm), but fly mortalities were not different in four days.

5. CONCLUSION

In the test conducted among four cassava preparations (sun-dried chips, fresh chips, fermented dough, and flour) with cocoa beans as the control, sun-dried chips was the most attractive to *A. fasciculatus* and thus the obvious choice for the preparation of the bait. Soaking the chips in brown sugar solution and fermenting for 12 hour further enhanced the attractiveness of sun-dried chips to *A. fasciculatus*. Deltamost, amongst Fastrack and Confidor pesticides, emerged superior with the least mean lethal time at the three different concentrations, knocking down the insect 4-6.33 minutes after exposure to the bait with higher concentration of pesticide having lower mean lethal time and vice versa. In addition, another comparison to determine the persistence of the three pesticides in cassava bait at three different levels of concentration showed Deltamost as the most persistent pesticide maintaining potency 21 - 30 days; higher concentration being more potent for a longer period than lower concentration. Furthermore, cassava containing Deltamost insecticide was the most effective attract-and-kill bait for the control of *Araecerus*-infested bagged cocoa beans under cage, in that, at 72 hours after introduction of the insects, 76.7 - 86.7% had been attracted and killed by the bait. In all, cassava bait at 25% of the recommended dosage of Deltamost pesticide was at equal strength at $p > 0.05$ with the 50 and 75% and could, therefore, be used for the insecticidal cassava bait preparation to make the bait much safer and cheaper.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Krähmer A, Engel A, Kadow D, Ali N, Umaharan P, Kroh LW, Schulz H. Fast and neat — Determination of biochemical quality parameters in cocoa using near infrared spectroscopy. Food Chemistry. 2015;181:152–159.
2. Ho VTT, Zhao J, Fleet G. The effect of lactic acid bacteria on cocoa bean fermentation. International Journal of Food Microbiology. 2015;205:54–67.
3. Afoakwa EO, Quao J, Takrama J, Budu AS, Saalia FK. Effect of pulp preconditioning on acidification, proteolysis, sugars and free fatty acids concentration during fermentation of cocoa (Theobroma cacao) beans. International Journal of Food Sciences and Nutrition. 2011;62(7):755–764.
4. Afoakwa EO. Chocolate science and technology. John Wiley & Sons; 2016.
5. Afoakwa EO. Chocolate science and technology. UK: Wiley-Blackwell Publishers. 2010;382.
6. Knudsen MH, Fold N. Land distribution and acquisition practices in Ghana's cocoa frontier: The impact of a state-regulated marketing system. *Land Use Policy.* 2011; *28*(2):378-387.
7. Dwinger F. Infrastructure for Cocoa: The story of Ghana's Trade Relationship with China; 2010.
   Available:http://www.consultancyafrica.com/index.php?
   (Retrieved on November 4, 2010)
8. Osei I. Challenges of quality standards in the cocoa industry. A Presentation at the African Cocoa Summit; 2007
   Available:http://www.mofep.gov.gh/documents/cocoasummit_p3.pdf
   (Date assessed) 19th October, 2011.
9. Bateman R. Revised Ed. Pesticide use in cocoa, A guie for training administrative and research staff. 2010
   Available:http://www.dropdata.org/cocoa/cocoa_pesticide manual_Ed2.pdf
   (20th September, 2011)
10. Jonfia-Essien WA. Cocoa storage in Ghana. In: Hordges, R. J. and Farell, G.(Eds.), Crop Post-harvest: Science and Technology Vol. 2; Durables. Blackwell Science Ltd., UK. 2004;274.
11. USDA. Agricultural Research Service, National Program 308. Methyl Bromide Alternatives Action Plan 2007 – 2012; 2006
12. Hodges R, Graham F. Crop post-harvest: Science and technology, durables case studies in the handling and storage of durable commodities. 2008;2:92–95.
13. Renju T. Evaluation of newer insecticidal poison baits against lepidopterous crop pests. Msc. Thesis, July 2007, Department of Agricultural Entomology, University of Agricultural Sciences, Dharwad; 2007.
14. Boateng BA and Chijindu EN. Presence of and damage to processed cassavachips by Araecerus *fasciculatus* (De Geer); 2008
    Available:http://www.aensionline.com/jasr/2008/939 -944.pdf
15. Hiremath IG, Bhuti SG, Kachapu, MD, Viraktamath S. Lingappa S. Mass killing of moths- A new approach in the management of armyworm, *Mythimna seperata* (Walker). Karnataka J. Agric. Sci. 1990;3:128-130.
16. Metcalf RL. Plant kairomones in insect ecology and control. Chapman and HallPublishers, 2-6 Boundary Row, London SEI 8HN. 1992;1–23.
17. Viswanadham JK, Punnaiah KC, Rao CRS. (Studies on certain baitcompositions against tobacco caterpillar, *Spodoptera litura* Fabricus (Noctuidae;Lepidoptera). Andhra Agric. J. 1986;33:16–19.
18. Adu-Mensah J, Owusu-Akyaw M Mochiah MB. Insect pest of driedcassava (kokonte) in the Ashanti and Brong Ahafo regions of Ghana. Journal of the Ghana Science Association. 2007;9(2):9–17.
19. Wakefield ME. Storage arthropod detection-current status and future directions. 9thInternational Conference on Stored Product Protection. 2006;371–384.
20. Foster RN, Quinn MA, Reuter KC, Colleto D, Houston R, Puclick MJ, Scott A, Radsick B. Comparison of single and multiple applications of aninsecticidal bait for controlling grasshoppers (Orthoptera: Acrididae) on mixed-grass Prairie. Journal of the Cansas Entomological Society. 1999;72(2):181-189.

21. Tublad B. Poison bran against cutworms in a nursery. Vaxtskyddsnotiser. 1947;4:53-55.
22. Devaiah MA. Studies on cutworm in Mysore state and their control. M. Sc. (Agn) Thesis, University of A gric. Science, Bangalore India; 1973.
23. Parasuraman S, Jayaraj S, Gopalan M, Kamaraswami T. (Attraction of *Spodoptera litura* (Fabr.) larvae to baits. Indian Journal of Agric. Science. 1985;55:773-774.
24. Müller GC, Beier JC, Traore SF, Toure MB, Traore MM, Bah S, Doumbia S, Schlein Y. Successful field trial of attractive toxic sugar bait (ATSB) plant spraying methods against malaria vectors in the *Anopheles gambiae* complex in Mali,West Africa. Malaria Journal. 2010;9:210:1475-2875.
Available:http://www.malariajournal.com/content/9/1/210
25. Barry JD, Polavarapu S. Feeding activity and attraction of blueberry maggot (Diptera: Tephritidae) to protein baits, ammonium acetate and sucrose. Journal of Economic Entomology. 2004;97(4): 1269–1277.
26. Müller GC, Schlein Y. Different methods of using attractive toxic sugar bait (ATSB) for the control of *Phlebotomus papatasi*. Journal of Vector Ecology. 2011;36:64–70.
27. Obeng-Ofori D. Management of stored product arthropod pests. In: Post-HarvestScience and Technology (Eds.: Cornelius, E. W. and Obeng-Ofori D. 2008; 92- 145.
28. Rint JR. Biology of the coffee bean weevil, *Araecerus fasciculatus* de Geer Coleoptera: Anthribidae and its susceptibility to insecticides. In: Naewbanji, J. O.(Ed.). Advances in grain postharvest technology generation and utilization, Bankok (Thailand); Asean Grain Poastharvest Programme. 1989;143–157.
29. Mangan RL, Moreno DS, Thomson DG. Bait dilution, spinosad concentration and efficacy of GF-20 based fruit fly sprays. Crop Protection. 2005;25:125–133.
30. Revis HC, Miller NW, Vargas RI. Effects of aging and dilution on attraction and toxicity of gf-120 fruit fly bait spray for melon fly control in Hawaii.Journal of Economic Entomology. 2004;97(5):1659-1665.
31. de Groot I. Protection of stored grains and pulses. Agrodok Series 18, (5th Ed.). 2004; 39–47.

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